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ASSESSING THE POTENTIAL ROLE OF SPIDERS AS BIOINDICATORS IN ASHTOUM EL GAMIL NATURAL PROTECTED AREA, PORT SAID, EGYPT

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ABSTRACT

Egypt's biodiversity is continually under risk as well, its assessment, and preserving are major challenges. Globally, the using of invertebrates as bioindicators based on biodiversity to evaluate the effects of changes in habitat structure have expanded in the recent few decades in order to natural the increasing pressure upon existing protected areas. The present study was carried out at Ashtoum El-Gamil protectorate Port Said, Egypt, for investigating the role of spiders in the environmental impact assessment in the protectorate related to different types of disturbance. Using pitfall traps, a total of 370 adult specimens were collected from 12 sites belong to 46 species from 19 families. The disturbed site of petroleum factories area was recorded the lowest value of species abundance and richness with 7 and 4 respectively with high significant difference ($P < 0.05$). The TWINSPAN, Spiders indicator species, and DCA analysis separated the four natural sites from the eight disturbed sites. The CCA showed that the plant species *Mesembryanthemum forsskalei* and sand percentage of the soil ($P < 0.01$.) were correlated with the natural sites. Remarkably, the use of spiders as bioinicators was fundamentally valuable to assess the various causative threatened impacts of biodiversity disturbance in Ashtoum El-Gamil protectorate.

Key words: spiders, Ashtoum El-Gamil, bioindicator, Araneae, biodiversity.

INTRODUCTION

Worldwide changes, from habitat degradation and exotic species to anthropogenic climate change, have commenced the sixth great mass extinction event in Earth's. Nowadays, biodiversity faces a disaster, human activities raised the rate of species extinctions to a thousand or more times (Pimm *et al*.,1995) .

The current elevation in human activities puts unprecedented pressure on natural processes and if continued ultimately destroy the affected ecosystems (Pinto *et al*., 2008). This crisis has several negative effects for humanity, encompassing economies, health, environmental services, and moral and spiritual prosperity (Wilson, 2002). There is therefore an increasing demand of monitoring and depicting trends and status in ecosystems (Pinto *et al*., 2008).

As species become endangered and disappear, the incorporation and maintenance of protected areas have growingly been regarded as imperative for fending off the habitat loss and conserving the exceptional rates of plant and animal endemism that are criteria to hotspot status and to protect sites of global biodiversity significance.(Sodhi *et al*., 2008).

Protected areas are now acknowledged as an essential part of sustainable development strategies. They are a fundamental pillar of biodiversity conservation with 12% of land presently under protection and a pledge to expand this to 15–20% by 2020 (Bertzky *et al*., 2012).

Egypt has 30 protectorates, they comprise about 15% from its total area, and their number is expected to reach 48 protectorates by 2017 comprising about 17% from the total area of Egypt.

Ashtoum El-Gamil protectorate is located 13 km^2 to the west of Port Said town and covers an area of about 180 km^2 lying completely inside Lake Manzala. The protectorate include new and old El-Gamil inlets; as well as the historical Tennis Island, with an area of about 8 km^2, that lies on the south west of Port Said city .The historical Tennis island surrounded with water at a distance of about 300 m from all sides.

Natural environment in Egypt has been exposed to many shapes of impairment that menace its safety, such as the presence of preserved natural area within the urban context, short of funding. Also some of our protected areas suffer from conflict in responsibilities between relevant agencies (El Khateeb, 2006). The wetland sites of Ashtoum El-Gamil (Lake Manzala) are under escalating stress due to extensive development of natural gas investments and urbanization.

The intricacy of ecosystems and their biological communities has enforced conservation biologists to evolve alternative methods to monitor interchange that would be too costly or difficult to measure directly (Landres *et al*., 2005; Meffe & Carroll, 1997). Scientists hence use certain taxa that display determinable responses to the environmental changes as indicators of the state and quality of this environment. Bioindicators interact to data and sophisticated information on environmental conditions and, thus, afford a fair assessment on the ecological state of the environment. These bioindicators should perfectly mirror abiotic or biotic state of an environment, expressing the effect of environmental change on a habitat, community, or ecosystem, or is indicative of the diversity of a subset of taxa, or of the whole diversity, within an area (McGeoch , 1998).

Invertebrates, with their short life-cycles, comparatively easy to sample, quick responses to environmental changes, great abundances and high diversity of species, can be used as valuable bioindicators which indicate some measure of the character of the habitat within which they are found (Buchholz, 2010; Pearce & Venier, 2006).

Spiders are the best diversified and abundant with over 43600 recognized species invertebrate (Platnick, 2013) generalist predators in terrestrial ecosystems, they are species rich and known to have well-defined habitat preferences (Wise, 1993; Foelix, 1996). This ubiquity, diversity and ecological role of spiders makes them an excellent bioindicators of ecosystem management practices because they can be easily collected and identified and are differentially sensitive to natural and anthropogenic disturbances (Pearce & Venier, 2006). They are characterized by high taxonomic diversity, display taxon and guild responses to environmental change, intensely sensitive to small changes in habitat structure, including vegetation complexity, litter depth and microclimate characteristics (Wise, 1993; Uetz, 1991) according to (Kaltsas *et al*., 2014) spiders have proved to be good bioindicators of anthropogenic disturbance.

The main target for conservationists is the protection of little-known or unknown organisms, responsible for key ecological processes that keep the maintenance of ecosystems (Paschetta *et al*., 2013)

The aim of this study is to assess the environmental impact on spider assemblage that

exists amongst various habitats and identify environmental factors underlying the patterns of association in Ashtoum El-Gamil protectorate, Port Said, Egypt. Given the condition of this diverse and sensitive group, the results of this paper will provide insights into the immediate effects of the natural environmental variation on key groups like spiders, a taxon that has been rather neglected in conservation assessments in Egypt.

MATERIAL AND METHODS

The study area

Lake Manzala is located in the north east quadrant of the Delta between 31°00′ and 31° 30′ N latitude and 31°45′ and 32°22′ E longitude. It is bounded by the Mediterranean Sea at the north, Suez Canal at the east, Damietta province in the North West, and Dakahlia province in the southwest. Ashtoum El-Gamil & Tennis island is located in the western north corner of Lake Manzala including new and old El-Gamil inlets; as well as the historical Tennis island, with an area of about 8 km^2, that lies on the south west of Port Said city.

Sampling

Spiders were sampled seasonally from July 2011 to May 2012 by pitfall traps. Twelve sites belonging to five localities were chosen; four natural sites at Military missile base area *Qada el saro7'ya* (Q1, Q2, Q3 and Q4) and eight sites representing four different impacts two sites for each impact; Petroleum factories area (F1and F2), Fishermen's dwelling area *Boz El Balat* (B1and B2), Quail farm area *Seman* (S1 and S2), and Grazing area *Tennis* (T1and T2) respectively. Within each site 15 traps fixed along 150 m. Line transect with 10 meters in between to minimize among-trap interference. The coordinates of each site were recorded using a hand-held Global Positioning System (Garmin, GPSШ plus) with description of habitat characteristics of soil and flora.

Soil Analysis

Three soil samples at each site, at a depth of 0-30 cm and at 50 m intervals along each line transect were taken. Physical and chemical properties of soil were measured at the different study sites (organic matter, moisture, pH values, electric conductivity and soil texture) according to (Wilde *et al*., 1979).

Vegetation

The vegetation at each site was recorded as presence and absence of plant species. Three quadrates (20 x 20 m) were placed at 30 m regular intervals along the study site. Species were collected and identified in the laboratory of Botany at Ashtoum El- Gamil protectorate.

Data analysis

Spider species richness, abundance, diversity (Shannon and Simpson diversity indices) and evenness were calculated using the PC-ORD program for Windows version 4.14 (McCune & Mefford, 1999). Differences in spiders abundances, richness and evenness between sites were compared using one-way analysis of variance (ANOVA) (Zar, 1999) using the SPSS for Windows 12 statistical software package (SPSS, Inc. 1996), Only the adults specimens were included in the analysis.

Classification and Ordination

Two-way indicator species analysis (TWINSPAN) was carried out using the statistical package PC-ORD for Windows version 4.14 (McCune & Mefford, 1999). Two ordination techniques were applied: Detrended correspondence analysis (DCA) (Hill & Gauch 1980) and canonical correspondence analysis (CCA) (Ter Braak, 1987). DCA was performed using the PC-ORD package. Only common species that were found at three or more sites were used in the DCA and CCA analysis. The CCA was done in the forward selection mode of the CANOCO program (Ter Braak, 1987), and the significance of each variable was tested in a sequential fashion using a Monte-Carlo simulation algorithm before it was added to the final model. All variables that were significant at $p<0.05$ were included in the final model.

Indicator Species Analysis

Indicator species analysis was performed using the PC-ORD package on the species abundance data using the number of groups shown in the cluster and the two ordination methods. In this analysis, both of the species frequency and the relative abundance values are combined to estimate the degree that each species is characteristic for a group of sites. This degree is given by the species' indicator value (IV). The highest indicator value for a given species across group is saved as a summary of the overall indicator value of that species and evaluated by the Monte Carlo method, with randomly reassigned SUs (sample units) to groups taking place 1000 times (McCune & Grace, 2002).

RESULTS

During the study period, a total of 46 spider species were sampled by pitfall traps, which represent 70 % of the estimated total species richness by the First-order jackknife estimate.

Species abundance, richness, diversity, and evenness

A total of 991 spiders were collected during the study period; 621 immatures and 370 adults belonging to 19 families and 46 species. The site S2 had the highest values for spider species abundance, richness and Shannon diversity index (79, 17, and 2.134) respectively. While, the highest value of Simpson diversity index was recorded in S2 site (0.8217), and the highest value in species evenness was in T2 site (0.967). The F1 site has recorded the lowest value of species abundance and richness with 7 and 4 respectively. T1 has the lowest value of Shannon diversity index (0.588). T1 site showed the lowest Simpson diversity index and species evenness as well 0.258 and 0.365 respectively (Figures 1 and 2).

The One-Way ANOVA analysis showed that there was a highly significant difference of species abundance between the twelve sites ($\chi2 = 174.67$, d.f. = 11 and $P < 0.01$), while a slightly significant difference has been shown in species richness and Shannon diversity index ($\chi2 = 20.34$, d.f. = 11 and $P < 0.05$) and ($F11, 47 = 1.93$ and $P<0.06$). Both the species evenness and Simpson diversity index showed no significant difference between different sites (Figures 1 and 2).

Nearly 45 % of the total species richness was represented by three families; Lycosidae had the greatest number of species (8), followed by Theridiidae (6) and Salticidae and Gnaphosidae (5). The most abundant species was *Halodromus barbarae* (Philodromidae); totally about 44 individuals (11.6%). Followed by the *Pardosa* sp.(lycosidae) (n = 43, 11.4%) (Figure 1).

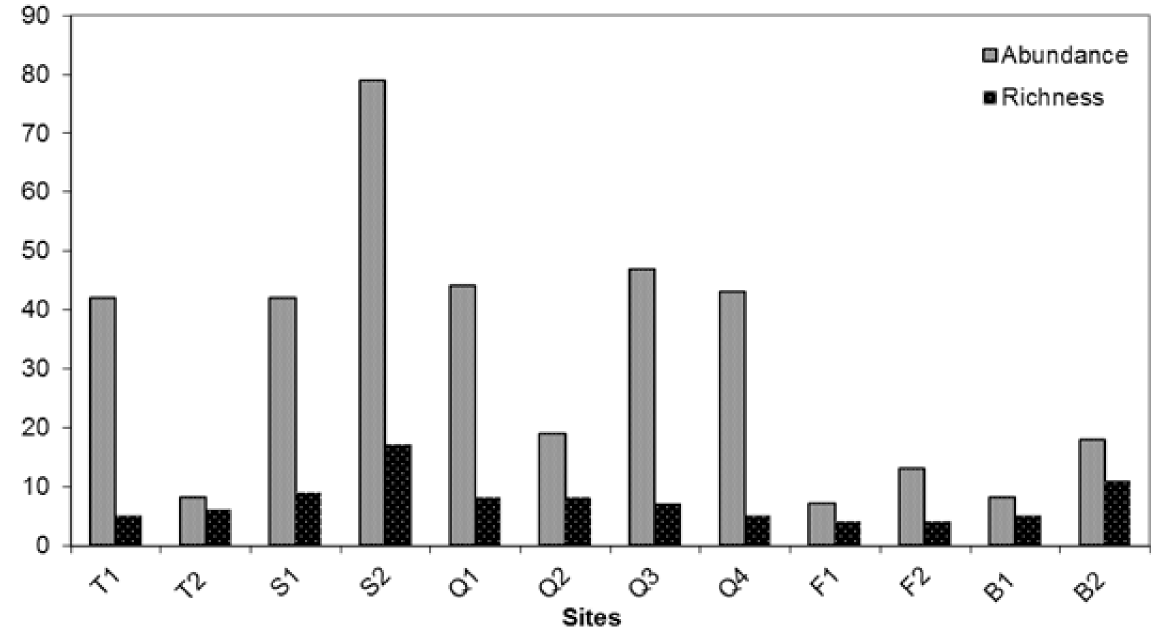

Figure 1 The spatial variation in species abundance and richness of spiders among study sites during the period of study.

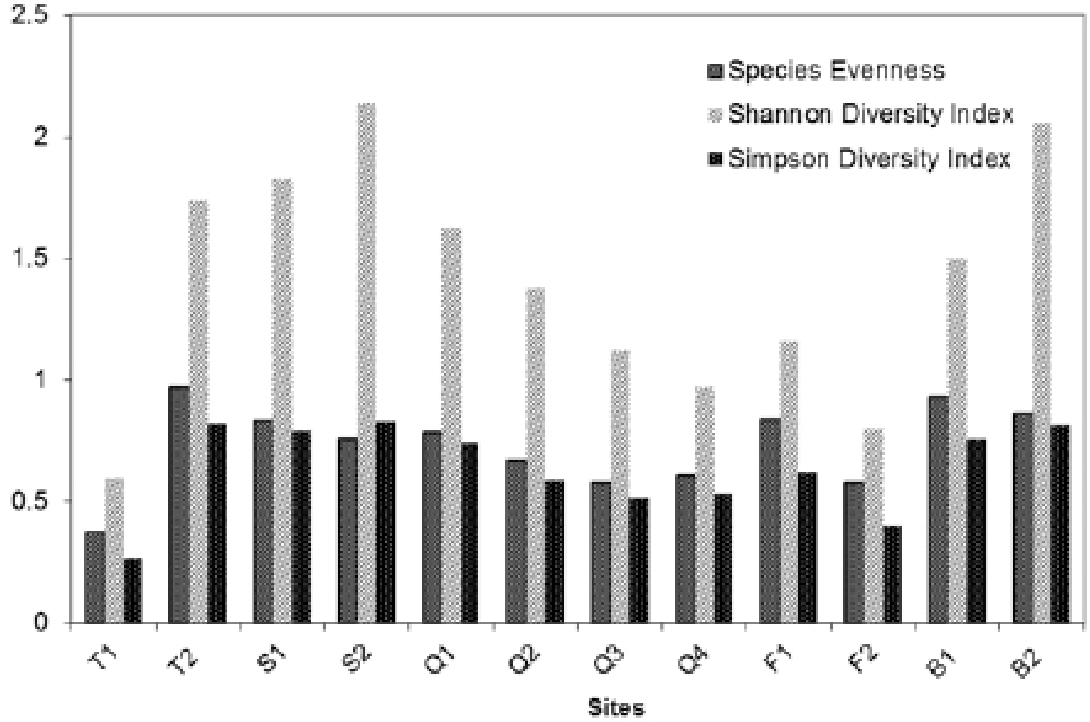

Figure 2 The spatial variation in species evenness, Simpson and Shannon diversity indices of spiders among study sites during the period of study.

Two-Way Indicators Species Analysis (TWINSPAN) & Indicator species Analysis

The Two-way Indicators Species Analysis of spiders species (TWINSPAN) produced three clusters groups by two divisions (Figure 3). The first division separates the four natural sites (Q1, Q2, Q3 and Q4) from the eight disturbed sites (T1, T2, S1, S2, B1, B2, F1and F2) on the base of the indicator species *Oxyopes* sp. (Oxyopidae) and *Pardosa* sp. (Bl.2) (Lycosidae) which were found in the first group. The second division showed the spider species *Wadicosa fidelis* (Lycosidae) as an indicator species for the group (T1, T2 and B2) separating the five sites (S1, S2, B1, F1 and F2).

Spiders indicator species analysis confirmed the results of TWINSPAN analysis where it showed a three spider indicators species significantly correlated with the study sites. *Wadicosa fidelis* (IV=100, p<0.01) was found only in Tennis sites and one of Boz El-Balat sites (T1, T2 and B2). The spider indicator species *Zelotes* Sp. (IV=91.3, p<0.01) recorded a significant correlation with Seman farm sites and one of Boz El-Balat sites (S1,S2 and B1). On the other hand, the natural sites (Q1, Q2, Q3 and Q4) were significantly correlated with the presence of indicative species *Oxyopes* Sp. (IV=96.5 , p<0.01).

Detrended Correspondence Analysis (DCA)

Figure 4 shows the ordination of the DCA analysis of the Spiders species collected from the study sites. The study sites were spread out along the first two axes and tend to cluster into three groups. The first axis separated the natural sites (Q1, Q2, Q3 and Q4) on the left side of the axis along with their characteristic species from the disturbed sites on the other side of the axis with their indicator species. Axis 2 separated the disturbed sites into two groups, Tennis sites and one of the factories site (T1, T2 and F2) on the upper side of the axis and Seman farm sites , Boz el balat sites and one of the factories sites (S1, S2, B1, B2 and F1) near the lower side. The two axes accounted for 36.5 % of the total variation.

Canonical Correspondence Analysis (CCA)

CCA analysis between spiders species and vegetation cover:

Figure 5 shows the Canonical Correspondence Analysis (CCA) of spiders species collected by pitfall traps with the vegetation cover. The forward selection procedure of CCA resulted in the retention of two plant species. The *Mesembryanthemum forsskalei* (P < 0.01.) was correlated with the natural sites (Q1, Q2, Q3 and Q4) while the rest of the sites were correlated with the value of *Phragmites australis* (P <0.01). The Sum of all canonical Eigen-values of the CCA axes was (1.3) with the first two axes accounted for 30 % of the total variation.

CCA analysis between spiders species and soil parameters:

Figure 6 shows the Canonical Correspondence Analysis (CCA) of spiders species with the soil variables. The forward selection procedure of CCA resulted in the retention of sand percentage (P <0.01). The analysis revealed a three groups two of them were positively correlated with this soil factor (Q1, Q2, Q3 and Q4) and (B1, B2, S1, S2, F1 and F2) while the third group (T1 and T2) showed a negative correlation with the sand percentage. The first two axes accounted for 30 % of the total variation.

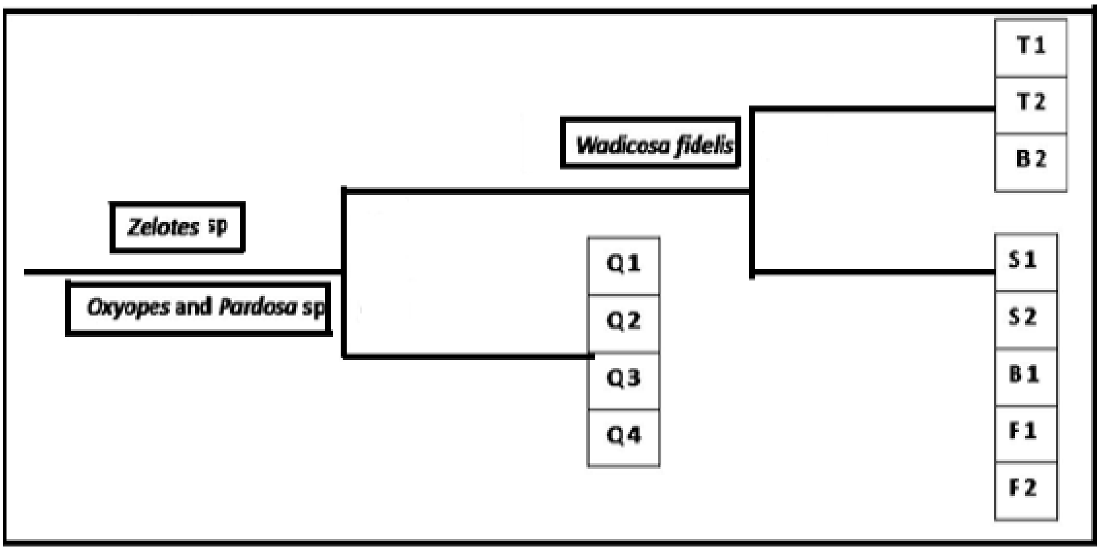

Figure 3 Dendrogram showing the twelve sites interpreted from the TWINSPAN analysis of spiders species together with the indicator species at each division.

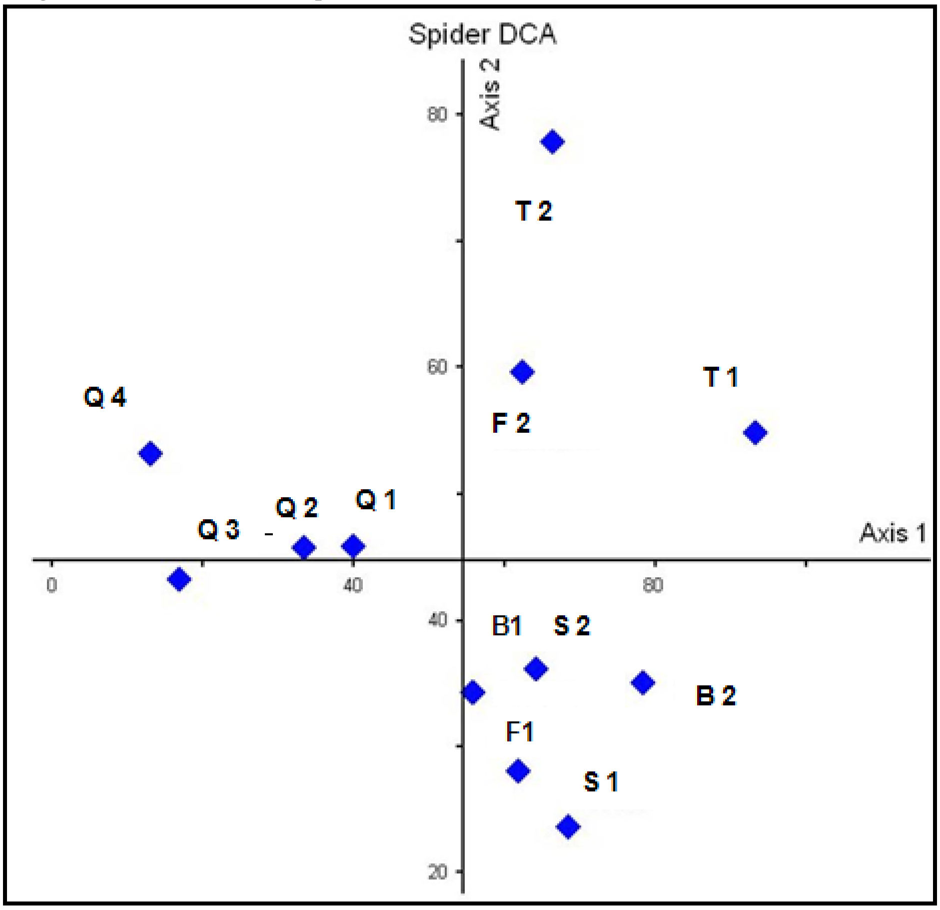

Figure 4 Detrended Correspondence Analysis (DCA) of Spiders species for the study sites in Ashtoum El-Gamil protected area.

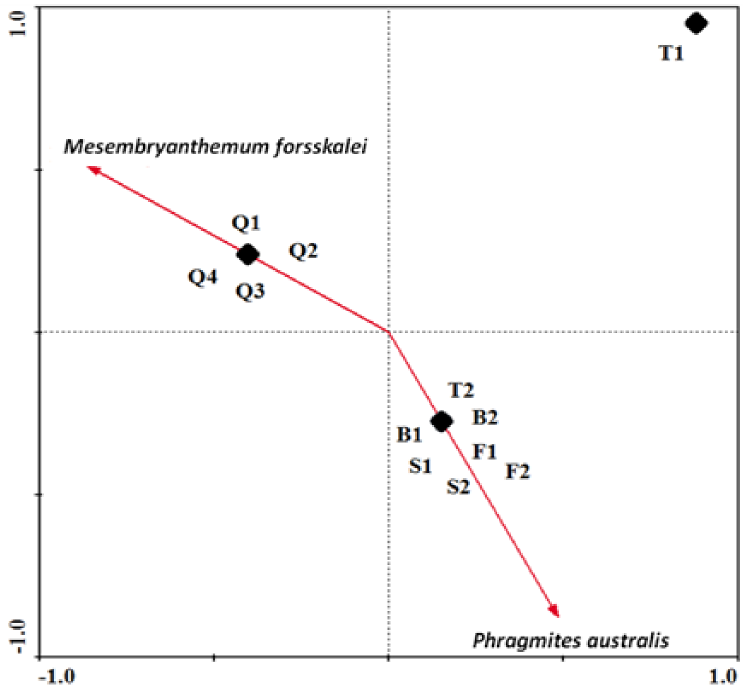

Figure 5 Ordination diagram based on a canonical correspondence analysis for the twelve study sites and vegetation cover bi plot in Ashtoum El-Gamil protected area.

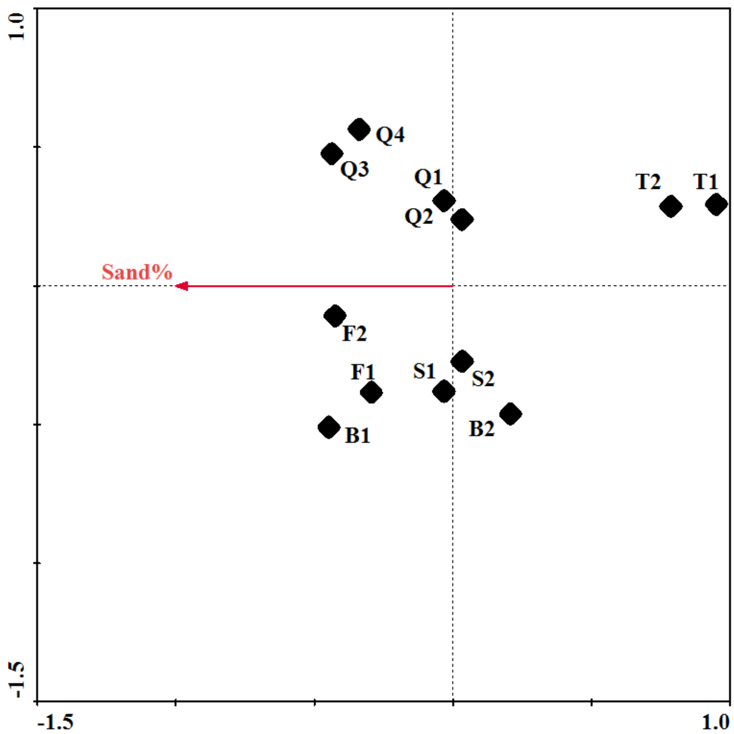

Figure 6 The Canonical Correspondence Analysis (CCA) of Soil parameters for the study sites in Ashtoum El-Gamil protected area.

DISCUSSION

No previous work on spiders has been conducted in Ashtoum El-Gamil protectorate; therefore the study represents new distribution records for all species which additionally emphasizes the significance of maintaining the conservation status of this landscape. Our study proposes a group spider species provide trustworthy evaluation of the habitat status in relevance to the heterogeneity and disturbance gradient. Spider assemblages are well appropriate to differentiate habitat quality, since many spiders often depend on a distinct complex of environmental habitat factors with regard to species-specific ecological demands.

The results obtained from spiders species effort curve showed stability of the population curve after the third trip which means that the most common species were trapped at the study area and both the sampling periods and the pitfall trap numbers are adequate for obtaining a complete picture of the spider fauna at the study sites. However, to continue using these methods in their current form, to add the remaining uncollected species would be an inefficient use of resources. This result agreed with (Colwell & Coddington, 1994) where they argued that species accumulation curves based on trapping effort represent an even method, without bigotry of a collector's attention being given to rare species.

At disturbed sites, spider assemblage maintained sizable abundance, richness and diversity, partially yet higher than in the natural sites. The intermediate disturbance hypothesis would possibly give an interpretative framework for the pattern detected (Connell, 1978). Disturbance innovates new opportunities for species not launched in natural sites, and the habitat patches resulting from regeneration after patchy disturbance moreover increases the number of niches available. Also the diversified vegetation structure of the disturbed sites may explain this difference in spider abundance, richness and diversity from the natural sites. The abundance of these species can be explained by the fact that most of these species are generalist or open field species (Varet *et al.*, 2014). Preceding studies have showed that there are clear correlations between spider abundance, species richness , diversity and the structural diversity of the habitat (Halaj *et al.*, 1998; Cai *et al.*, 2010).

Habitat heterogenity supports sufficient alternative prey for the generalist predators to set up their populations and get benefit from a variety of natural food resources accessible in more structurally diverse habitats (Siira-Pietikainen *et al.*, 2003; Cai *et al.*, 2010). In specific, the conformation of ground vegetation and the ensuing microclimate are virtually to influence the diversity and distribution of spider species and this is likely the main reason for the shaping of specific species assemblages in a habitat (Hurd & Fagan, 1992; Gibson *et al.*, 1992).

The species composition of spiders varied clearly and mirrored the entire variety of habitat forms investigated within the study area at Ashtoum El-Gamil protectorate. The result of TWINSPAN, DCA and CCA analysis showed that the spider assemblages were differentiated among the habitats examined, with the four natural sites (Q1, Q2, Q3 and Q4) being particularly distinct from the other disturbed sites in terms of species composition. Species distribution was constrained mainly by environmental conditions (vegetation cover and soil type) in accordance with numerous other studies (Downie *et al.*, 1999; Perner & Malt, 2003; Beals, 2006; Lambeets *et al.*, 2007)

The CCA analysis showed that the two plant species (*Mesembryanthemum forsskalei* and

Phragmites australis) and the soil sand percentage are the significant factors for this separation. The physical structures of the environment possibly have a consequential impact on spider species composition. For instance, soil moisture has been found to positively affect spider density (Kajak *et al*., 2000), whereas Usher (1992) found spider assemblage structure was influenced by a wet-dry gradient.

Regarding the effect of vegetation structure on ground dwelling spider assemblages it is not surprising that the spider fauna diverged between the natural and disturbed sites. The natural sites surveyed exhibited considerable variation within the plant species composition, including *Mesembryanthemum forsskalei, Sarcornia fruticos* and *Zygophyllum coccineum*; whereas, the common reed *Phragmites australis* was abundant in the disturbed sites. In most habitats, plant communities figure out the physical structure of the environment, and therefore, have a substantial impact on the distributions and interactions of animal species (Lawton, 1983; McCoy & Bell, 1991). Vegetation intricacy has been frequently perceived as one of the most crucial factors in determining the presence of spider, moreover their species richness and composition (Downie *et al*., 2000; Borges & Brown, 2001).

Data concerning habitat preferences of the indicators species *Oxyopes* sp. (Family Oxyopidae) found in the natural sites are not available to date. However, based on this study, it is assumed that this species is preferable in the sunshine, running and jumping over leaves of small shrubs. The same applies to those two indicators for the disturbed sites *Wadicosa fidelisa* (Family Lycosidae) and *Zelotes* sp. (Family Gnaphosidae). The Lycosidae members likely to forage on flat open surfaces, and hence, are most abundant in shallow, compacted litter. While the members of the family Gnaphosidae are known to forage in a less active way, or dwell concealed shelter, and are more abundant in more intricate depth litter (Uetz, 1991; Hepner & Paulus, 2009).

Currently, Gnaphosidae includes 2134 species and 118 genera worldwide (Platnick, 2013) and is also one of the most diverse and dominant spider families in the Mediterranean region. More importantly, Gnaphosids are known to respond to anthropogenic disturbance in the eastern Mediterranean (Kaltsas *et al*., 2014)

These divergences in family composition illustrate the distinct niches that each of these habitat types provide. Nevertheless, the associations between the species abundance and the structural characteristics of the habitat are the beginning in expanding our information of the ecology of epigeal spiders in Ashtoum El-Gamil protectorate. However, to conclude the functional relationship between habitat features and the species survival, we also need to have adequate information of the life history and other biological factors of each species. At the end, our results agreed with (Kaltsas *et al*., 2014) where spiders have proved to be good bioindicators of anthropogenic disturbance as an applied conclusion of the field study.

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